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Process for removing water and hydrocarbons from a natural gas stream

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PROCESS FOR REMOVING WATER AND HYDROCARBONS FROM A  
NATURAL GAS STREAM

FIELD OF THE INVENTION

The invention relates to a process for removing water and hydrocarbons from a natural gas stream.

BACKGROUND OF THE INVENTION

5           Processes for removing water or hydrocarbons from a natural gas stream are known in the art. The need for such processes arises from the fact that in the event that untreated natural gas is transported through pipeline systems the pressure loss, which is inevitable  
10           in pipeline systems, causes liquids, arising from the condensation of water or hydrocarbons, to be formed. Slugs of these liquids can cause problems, such as damage to pipelines and distribution systems.

          To prevent liquids from forming, water or  
15           hydrocarbons should therefore be removed from natural gas prior to deployment in a gas transportation system.

          For pure components, the temperature at which the first liquids form is referred to as the dewpoint. For mixtures, such as natural gas, a two-phase region exists  
20           where both vapours and liquids are present. For natural gas mixtures, this two-phase region is defined by a relationship between pressure and temperature above, which liquids cannot form anymore. These are referred to as cricondenbar (highest pressure at which a vapour-  
25           liquid equilibrium is present) and cricondentherm (highest temperature at which a vapour-liquid equilibrium is present) respectively. Temperatures higher than the

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cricondenthem and pressures higher than the cricondenbar cannot produce bubble or dewpoint conditions.

5 In order to prevent the formation of liquids in natural gas, the cricondenthem of the natural gas should be changed. In the case of natural gas with a low content of hydrocarbons, referred to a lean gas, or in the case when hydrocarbon liquid formation is allowable, only water removal is required. Generally, however, there is a need for the removal of both water and hydrocarbons from  
10 the natural gas, especially to achieve a certain desired cricondenthem.

#### SUMMARY OF THE INVENTION

Accordingly, the invention is a process for removing water and hydrocarbons from a gas stream comprising  
15 natural gas, C<sub>2</sub>, C<sub>3</sub>, C<sub>4</sub>, C<sub>5</sub>+ hydrocarbons and water, the process comprising the steps of:

- (a) cooling the gas stream to a temperature such that at least some water and some hydrocarbons will begin to condense into a first liquid water/hydrocarbon phase;  
20 (b) separating the first liquid water/hydrocarbon phase in a gas/liquid separator to create a regenerated gas stream;  
(c) leading the regenerated gas stream through a conduit of an accelerated velocity inertia separator, thereby  
25 creating a fluid stream flowing at accelerated velocity, and causing said fluid stream to cool to a temperature that is below a temperature at which water and hydrocarbons will begin to condense into a second liquid water/hydrocarbon phase;  
30 (d) separating the second liquid water/hydrocarbon phase from the regenerated gas stream to create a purified gas stream.

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DETAILED DESCRIPTION OF THE INVENTION

In step (a) of the process according to the invention, a gas stream comprising natural gas, C<sub>2</sub>, C<sub>3</sub>, C<sub>4</sub>, C<sub>5</sub>+ hydrocarbons and water is cooled to a temperature such that at least some water and some hydrocarbons will  
5 condense into a first liquid water/hydrocarbon phase.

Typically, the amount of C<sub>5</sub>+ hydrocarbons and water in the gas stream is higher than the total amount of components selected from the group of natural gas, C<sub>2</sub>, C<sub>3</sub>  
10 and C<sub>4</sub>.

The term "natural gas" is applied to gas produced from underground accumulations of widely varying composition. Apart from hydrocarbons, natural gas generally includes nitrogen, carbon dioxide and sometimes  
15 a small proportion of hydrogen sulphide. The principal hydrocarbon is methane, the lightest and lowest boiling member of the paraffin series of hydrocarbons. Other constituents are ethane, propane, butane, pentane, hexane, heptane, etc. Reference herein to C<sub>3</sub> and C<sub>4</sub> is to  
20 hydrocarbons having 3 or 4 carbon atoms respectively. Reference herein to C<sub>5</sub>+ is to hydrocarbons having 5 or more carbon atoms.

The lighter constituents, e.g. C<sub>1</sub> up to and including C<sub>4</sub>, are in gaseous phase at atmospheric temperatures and  
25 pressures. The heavier constituents, C<sub>5</sub>+, are in gaseous phase when at elevated temperatures during production from the subsurface and in liquid phase when the gas mixture has cooled down. Natural gas containing such heavier constituents is known as "wet gas" as distinct  
30 from dry gas containing none or only a small proportion of liquid hydrocarbons.

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Preferably, the pressure of the gas stream comprising natural gas, C<sub>2</sub>, C<sub>3</sub>, C<sub>4</sub>, C<sub>5</sub>+ hydrocarbons and water is between 60 and 90 bara, more preferably between 70 and 80 bara.

5            Preferably, the amount of water in the gas stream is between 0.5 and 40 wt%, more preferably between 1 and 30 wt%, most preferably between 1 and 20 wt%.

10           Preferably, the amount of C<sub>5</sub>+ hydrocarbons in the gas stream is between 1 and 20 wt%, more preferably between 5 and 10 wt%.

15           Preferably, between 0.5% and 90% of the water will condense, more preferably between 1.0% and 80%, based on the total water present as steam in the gas stream. Preferably, between 0.5% and 90% of the other water and hydrocarbons will condense, more preferably between 1.0% and 80%, based on the total water and hydrocarbons present in the gaseous phase in the gas stream.

20           Typically, the first water/hydrocarbon phase comprises water and C<sub>5</sub>+ as the principal components. Preferably, the water/hydrocarbon phase comprises between 5 and 90 wt% water, more preferably between 10 and 80 wt%, most preferably between 15 and 50 wt%, based on the total water/hydrocarbon phase.

25           In step (b) of the process according to the invention the first liquid water/hydrocarbon phase is separated in a gas/liquid separator to create a regenerated gas stream.

Typically, the regenerated gas stream is enriched in components selected from the group of C<sub>2</sub>, C<sub>3</sub> and C<sub>4</sub>.

30           Preferably, the regenerated gas stream comprises between 5 and 50 wt% of components selected from the group of C<sub>2</sub>, C<sub>3</sub> and C<sub>4</sub>, more preferably between 10 and 40 wt%, most



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preferably between 15 and 30 wt%, based on the total regenerated gas stream.

5 In step (c) of the process according to the invention the regenerated gas stream is led through a conduit of a accelerated velocity inertia separator, thereby creating a fluid stream flowing at accelerated velocity, and causing said fluid stream to cool to a temperature that is below a temperature at which water and hydrocarbons will begin to condense into a second liquid  
10 water/hydrocarbon phase.

Reference herein to an accelerated velocity inertia separator is to an apparatus wherein a fluid stream is induced to flow at accelerated velocity through a conduit, so as to decrease the temperature of the fluid  
15 in the conduit to below a temperature at which a selected component will condense into a second liquid water/hydrocarbon phase.

Preferably, the accelerated velocity inertia separator is a supersonic inertia separator wherein the  
20 velocity in the radially outer section and in the central part of the stream is supersonic. Suitable supersonic velocity inertia separators are described in US 6,280,502. The supersonic inertia separator causes the fluid stream to flow at supersonic velocity. This causes  
25 a rapid expansion, resulting in cooling of a compressible fluid stream. The cooling results in condensation of vapours to the extent that such cooling brings the temperature of the stream to a temperature below a point where components will condense to form a separate second  
30 water/hydrocarbon phase.

Suitably, the conduit is provided with swirl imparting means to impart a swirling motion to the stream of fluid flowing at accelerated velocity.

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Preferably, a swirling motion is induced to the stream of fluid flowing at supersonic velocity, thereby causing the water and hydrocarbons to flow to a radially outer section of the regenerated gas stream.

5        Preferably, a wing placed in the supersonic flow region imparts the swirling motion. Reference herein to the supersonic flow region is to the part of the conduit of the supersonic velocity inertia separator wherein the fluid stream flows at supersonic velocity.

10       Preferably, a shock wave is created in the stream that is upstream of the radially outer section and downstream of the location where the swirling motion has been imparted.

15       Preferably, the shock wave is created by inducing the stream of fluid to flow through a diffuser. A diffuser may be a diverging volume, or a converging and a diverging volume.

20       It was found that the separation efficiency is significantly improved if collection of the condensed particles takes place after the shock wave, i.e. in subsonic flow rather than in supersonic flow. This is because the shock wave dissipates a substantial amount of kinetic energy of the stream and thereby strongly reduces the axial component of the fluid velocity while the  
25       tangential component (caused by the swirl imparting means) remains substantially unchanged. As a result the density of condensable components in the radially outer section is significantly higher than elsewhere in the conduit where the flow is supersonic. It is believed that  
30       this effect is caused by the strongly reduced axial fluid velocity and thereby a reduced tendency of the particles to be entrained by a central "core" of the stream where the fluid flows at a higher axial velocity than nearer



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the wall of the conduit. Thus, in the subsonic flow regime the centrifugal forces acting on the condensed components are not to a great extent counter-acted by the entraining action of the central "core" of the stream, so that the condensed components are allowed to agglomerate in the radially outer section from which they are extracted.

In step (d) of the process according to the invention the second liquid water/hydrocarbon phase is separated from the regenerated gas stream to create a purified gas stream. Suitably, the second liquid water/hydrocarbon phase is separated in a first outlet stream from a radially outer section of the regenerated gas stream. Preferably, the remaining purified gas stream is collected in a second outlet stream from a central part of the regenerated gas stream. Typically, the second liquid water/hydrocarbon phase is enriched in C<sub>2</sub>+ components. Typically, the purified gas stream is depleted of components selected from the group of C<sub>2</sub>, C<sub>3</sub> and C<sub>4</sub>. Put differently, the purified gas stream is typically enriched in C<sub>1</sub>, compared to the regenerated gas stream. Preferably, the purified gas stream comprises between 0.05 and 20 wt% of components selected from the group of C<sub>2</sub>, C<sub>3</sub> and C<sub>4</sub>, more preferably between 0.1 and 15 wt%, most preferably between 0.5 and 10 wt%, based on the total regenerated gas stream.

Typically, the pressure of the purified gas stream is lower than the pressure of the regenerated gas stream. Preferably, the pressure of the purified gas stream is increased, for example using a compressor. More preferably, the pressure of the purified gas stream is increased to a value of between 50% and 100% of the pressure of the regenerated gas stream, most preferably

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to a value of between 60% and 90% of the pressure of the regenerated gas stream.

In a preferred embodiment, the gas stream is obtained by the steps of:

5 (e) contacting part of a feed gas stream comprising natural gas, C<sub>3</sub>, C<sub>4</sub>, C<sub>5</sub>+ hydrocarbons and water with a first adsorbent bed to create a first gas stream depleted of water and C<sub>5</sub>+ hydrocarbons;

10 (f) heating another part of the feed gas stream in a heating zone to obtain a heated feed gas stream and

(g) contacting the heated feed gas stream with a second adsorbent bed, the second adsorbent bed being in the regeneration mode, to obtain the gas stream.

15 Preferably, the pressure of the part of the feed gas stream in step (e) is adjusted prior to being contacted with the first adsorbent bed, in order to conform to the operating pressure of the adsorbent bed. Typical operating pressures of the first adsorbent bed are between 40 and 120 bar, preferably between 70 to 100 bar.

20 Preferably, temperatures in the first adsorbent bed are between 5 and 50 °C, more preferably between 15 and 40 °C, most preferably between 20 and 30 °C.

25 In the adsorbent bed, generally two zones, an equilibrium zone and a mass transfer zone, can be distinguished. In the equilibrium zone, the amount of adsorbed material is in equilibrium with the partial pressure of the component in the feed. In the mass transfer zone, the adsorbent is actively adsorbing the component from the gas stream.

30 Suitable adsorbents in the first adsorbent bed are solids having a microscopic structure. The internal surface of such adsorbents is preferably between 100 and 2000 m<sup>2</sup>/g, more preferably between 500 and 1500 m<sup>2</sup>/g. The

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nature of the internal surface of the adsorbent in the adsorbent bed is such that water and C<sub>5</sub>+ hydrocarbons are adsorbed. Suitably, the internal surface of the adsorbent is polar. Suitable adsorbent materials include materials based on silica, silica gel, alumina or silica-alumina.

Generally, water is preferentially adsorbed over hydrocarbons. C<sub>5</sub>+ hydrocarbons will generally be preferentially adsorbed over lighter hydrocarbons such as C<sub>3</sub> or C<sub>4</sub>. Therefore, the first gas stream is depleted of water and C<sub>5</sub>+ hydrocarbons. Typically, the amount of water in the first gas stream is between 0.01 and 10 wt%, preferably between 0.1 and 5 wt%, based on the total gas stream. Typically, the amount of C<sub>5</sub>+ hydrocarbons in the first gas stream is between 0.1 and 20 wt%, preferably between 0.5 and 10 wt%.

In step (f) of the preferred embodiment, another part of the feed gas stream is heated in a heating zone. Preferably, heating temperatures are between 150 and 450 °C, more preferably between 200 and 400 °C, or between 250 and 350 °C.

In step (g) of the preferred embodiment, the heated gas stream is contacted with a second adsorbent bed, the second adsorbent bed being in the regeneration mode, to obtain the gas stream. Adsorption of gas components from a gas mixture through solid adsorbents is a thermal exothermic process. This process can be reverted by applying heat to the adsorbent and adsorbate phase. If the heat applied is sufficient, the adsorbed components will leave the adsorbent internal surface and pores. To achieve complete regeneration, the adsorbent is once again cooled to its initial temperature. This reversion of the adsorption process is called regeneration.

Reference herein to the second adsorption bed being in

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the regeneration mode is to the second adsorption bed being subjected to conditions which will cause the adsorbed components to leave the adsorbent internal surface and pores. It will be clear to the skilled person that the first and second adsorbent bed will alternatively be either in the adsorbent mode or in the regenerating mode.

Preferably, the temperature of the second adsorbent bed is between 200 and 350 °C, more preferably between 250 and 325 °C, most preferably between 275 and 310 °C.

In the preferred embodiment, the gas stream obtained after step (g) is cooled to a temperature such that at least some water and some hydrocarbons will begin to condense into a first liquid water/hydrocarbon phase. Said first liquid water/hydrocarbon phase is then separated in a gas/liquid separator to create a regenerated gas stream. Said regenerated gas stream is then led through a conduit of an accelerated velocity inertia separator, thereby creating a fluid stream flowing at accelerated velocity. Said fluid stream is then caused to cool to a temperature that is below a temperature at which water and hydrocarbons will begin to condense into a second liquid water/hydrocarbon phase. Said second liquid water/hydrocarbon phase is then separated from the regenerated gas stream to create a purified gas stream.

Preferably, the purified gas stream is led to the first adsorbent bed. Typically, the purified gas stream is mixed with the part of a feed gas stream which is contacted with the first adsorbent bed in step (a) of the process according to the invention. Optionally, the pressure of the purified gas stream is adjusted prior to being contacted with the first adsorbent bed, in order to

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conform to the operating pressure of the adsorbent bed. Typically, the purified gas stream is enriched in  $C_1$ , compared to the feed gas stream.

5 The invention will now be illustrated by means of schematic figure 1. Figure 1 represents a non-limiting example of a preferred embodiment of a process according to the invention. Part of a feed gas stream comprising natural gas,  $C_2$ ,  $C_3$ ,  $C_4$ ,  $C_5+$  hydrocarbons and water and having a starting pressure is led via line 1 to a  
10 valve (2) to decrease the pressure. The part of the feed gas stream with a decreased pressure is led via line (3) to a first adsorbent bed (4) comprising solid adsorbent material. In the first adsorbent bed, water and  $C_5+$  hydrocarbons are adsorbed to create a first gas stream  
15 depleted of water and  $C_5+$  hydrocarbons which is led from the first adsorbent bed via line (5). Another part of the feed gas stream is led via line (6) to a heating zone (7) where it is heated. The heated part of the feed gas stream is led via line (8) to a second adsorbent bed (9),  
20 the second adsorbent bed being in the regeneration mode, to create a second gas stream enriched in water and  $C_5+$  hydrocarbons. This second gas stream is led via line (10) to a cooling unit (11) where it is cooled to a temperature such that water and hydrocarbons condense  
25 into a first liquid water/hydrocarbon phase. The cooled gas stream comprising the first liquid water/hydrocarbon phase is led via line (12) to a gas/liquid separator (13) where the first liquid water/hydrocarbon phase is separated and led from the gas/liquid separator via  
30 line (14). The resulting regenerated gas stream is led from the gas/liquid separator to a conduit of an accelerated velocity inertia separator via line (15). In the conduit of an accelerated velocity inertia separator,

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a fluid stream flowing at accelerated velocity is created. This fluid stream is caused to cool to a temperature that is below a temperature/pressure at which water and hydrocarbons condense into a second liquid  
5 water/hydrocarbon phase, the hydrocarbons in the water/hydrocarbon phase mostly comprising C<sub>3</sub>+ components. The second liquid water/hydrocarbon phase is separated from the fluid stream and is led from the accelerated velocity inertia separator via line (17). The resulting  
10 purified gas stream, enriched in C<sub>1</sub> compared to the feed gas stream, is led via line (18) to a compressor (19) where the pressure is increased. The pressurised purified gas stream is led via lines (20) and (3) to the first adsorbent bed.



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TS 1436 EPCC L A I M S

1. A process for removing water and hydrocarbons from a gas stream comprising natural gas, C<sub>2</sub>, C<sub>3</sub>, C<sub>4</sub>, C<sub>5</sub>+ hydrocarbons and water, the process comprising the steps of:

5 (a) cooling the gas stream to a temperature such that at least some water and some hydrocarbons will begin to condense into a first liquid water/hydrocarbon phase;  
(b) separating the first liquid water/hydrocarbon phase in a gas/liquid separator to create a regenerated gas stream;

10 (c) leading the regenerated gas stream through a conduit of a accelerated velocity inertia separator, thereby creating a fluid stream flowing at accelerated velocity, and causing said fluid stream to cool to a temperature  
15 that is below a temperature at which water and hydrocarbons will begin to condense into a second liquid water/hydrocarbon phase;

(d) separating the second liquid water/hydrocarbon phase from the regenerated gas stream to create a purified gas stream.

20 2. A process according to claim 1, wherein the gas stream has been obtained by the steps of:

(e) contacting part of a feed gas stream comprising natural gas, C<sub>3</sub>, C<sub>4</sub>, C<sub>5</sub>+ hydrocarbons and water with a  
25 first adsorbent bed to create a first gas stream depleted of water and C<sub>5</sub>+ hydrocarbons;

(f) heating another part of the feed gas stream in a heating zone to obtain a heated feed gas stream and;

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(g) contacting the heated feed gas stream with a second adsorbent bed, the second adsorbent bed being in the regeneration mode, to obtain the gas stream.

5 3. A process according to claim 2, wherein the purified gas stream is mixed with the part of the feed gas stream which is contacted with the first adsorbent bed.

4. A process according to claims 2 or 3, wherein the temperature of the first adsorbent bed is between 5 and 45 °C, preferably between 20 and 30 °C.

10 5. A process according to any one of claims 2 to 4, wherein the temperature of the second adsorbent bed is between 200 and 350 °C, preferably between 250 and 325 °C, more preferably between 275 and 310 °C.

15 6. A process according to any of claims 1 to 5, wherein the accelerated velocity inertia separator in step (c) is a supersonic inertia separator and the fluid stream flows at supersonic velocity.

20 7. A process according to claim 6, wherein a swirling motion is induced to the fluid stream flowing at supersonic velocity, thereby causing the water and hydrocarbons to flow to a radially outer section of a collecting zone in the stream.

25 8. A process according claim 7, wherein the swirling motion is imparted by a wing placed in the supersonic velocity flow region.

30 9. A process according to claim 7 or 8, further comprising the step of creating a shock wave in the part of the fluid stream that is upstream of the collecting zone and downstream of the location where the swirling motion has been imparted.

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10. A process according to claim 9 wherein the shock wave is created by inducing the fluid stream to flow through a diffuser.

CS/TS1436PD

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TS 1436 EPCA B S T R A C TPROCESS FOR REMOVING WATER AND HYDROCARBONS FROM A  
NATURAL GAS STREAM

The invention is a process for removing water and hydrocarbons from a gas stream comprising natural gas, C<sub>2</sub>, C<sub>3</sub>, C<sub>4</sub>, C<sub>5</sub>+ hydrocarbons and water, the process comprising the steps of:

- (a) cooling the gas stream to a temperature such that at least some water and some hydrocarbons will begin to condense into a first liquid water/hydrocarbon phase;
- (b) separating the first liquid water/hydrocarbon phase in a gas/liquid separator to create a regenerated gas stream;
- (c) leading the regenerated gas stream through a conduit of a accelerated velocity inertia separator, thereby creating a fluid stream flowing at accelerated velocity, and causing said fluid stream to cool to a temperature that is below a temperature at which water and hydrocarbons will begin to condense into a second liquid water/hydrocarbon phase;
- (d) separating the second liquid water/hydrocarbon phase from the regenerated gas stream to create a purified gas stream.

(Fig. 1)

CS/TS1436PD

